

Bioelectromagnetic Fields and Acupuncture

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ABSTRACT

Possible links between bioelectromagnetism and acupuncture are explored. The current status of research activities in bioelectromagnetism is reviewed, with particular emphasis on the emerging role of the geomagnetic field in weak-field biological interactions. We suggest that experiments be designed to study the functional dependence of acupuncture on the local magnetostatic field. We also suggest revisiting the earlier work in electrobiology by Burr, Lund, Becker, and others. This type of research, establishing the likelihood of functional endogenous electric fields in biosystems, has been neglected in recent years. The continuation of such studies may be the most reasonable direction to pursue in searching out the physiological basis for acupuncture.

NONTHERMAL BIOELECTROMAGNETIC PHENOMENA

In the following article we inquire whether the emerging science of bioelectromagnetism can play a role in helping us better understand acupuncture. There is much similarity between these two fields of research: both involve unexpected physiological responses to rather low levels of physical stimuli, both appear to be at odds with present biomedical paradigms, and both have been kept at arms length by the larger scientific community. Furthermore, both areas have developed empirical clinical applications in the absence of sound scientific understanding.

Much of the research activity in bioelectromagnetism involves interactions between electromagnetic (EM) fields and living systems at intensities that are well below thermal thresh-

olds. Some prefer to describe such *athermal* interactions as *subtle*. Others, myself included, use *weak*. Whatever the word, the meaning is that these interactions are not expected to occur and are difficult to explain on the basis of what we know in either physiology or in physics. Nevertheless, similar to what has happened in acupuncture, there are now dozens of observations that have been reported detailing such interactions.

Some argue (Adair, 1991; Weaver and Astumian, 1990) that these weak EM observations must necessarily be in error because simple predictions based on Maxwell's equations serve to set threshold interaction intensities below which the applied field is indistinguishable from ambient noise levels. This argument has been raised by critics, whose voices sometimes seem well above any respectable noise level for scientific debate (Liboff, 1995). This is espe-

cially the case in the attacks directed against the epidemiologically determined twofold odds ratio for leukemia found in children that are chronically exposed to 60-Hz, 2–4 mG power line magnetic intensities.

Suffice it to say that the critics, not the observations, are probably in error. The body of experimental work implicating weak low-frequency EM fields in biointeractions is now so extensive that many of those working in this area simply choose to ignore the present theoretical arguments, in anticipation of improved models that will better relate theory to reality.

We should all remember that the history of biophysics is replete with examples of theoretical disbelief in the cleverness of biological systems. In the 1930s, physics articles were published proving that it was impossible for pigeons to use the earth's magnetic field as a navigational aid, something regarded today as an irrefutable (albeit poorly understood) fact (Wehner, 1992). The Hodgkin-Huxley model of the action potential was also shown to be "impossible" because of the long diffusion times required for ions to migrate through the lipid membrane. This criticism disappeared when high-conductance transmembrane ion channels were discovered. There is a certain similarity between then and now. All the theoretical calculations that question the existence of weak bioelectromagnetic interactions involve calculations that are restricted to the electrical properties of the lipid membrane bilayer, thereby ignoring proteins and other biomaterials whose electrical characteristics are orders of magnitude different from the insulating lipids.

Many, if not most of the observations tending to confirm the existence of weak bioelectromagnetic interactions involving low-frequency (3–300 Hz) magnetic fields at intensities from 1 mG to 1000 mG (1 G). Such observations include effects on: (a) bone repair; (b) cellular response; (c) childhood leukemia; (d) plant growth; and (e) rat behavior.

Bone repair

Bone repair therapy is still limited by the Food and Drug Administration (FDA) to nonunions, whether occurring as a result of congenital pseudarthrosis or fractures that do

not heal. This is despite evidence in the literature (Lavine et al., 1971) that fresh fracture healing in animals is significantly hastened with EM treatment. EM treatments for humans now have a history going back to the 1970s when subcutaneous electrodes were first used (Lavine et al., 1972), and to when C.A.L. Bassett introduced noninvasive pulsed magnetic field treatments (Bassett et al., 1974). These approaches are now being rapidly replaced with calcium ion cyclotron resonance procedures (Deibert et al., 1994) that use 100-fold weaker magnetic intensities applied to patients for only 30 minutes per day (Fig. 1).

Cellular response

The EM studies on cell culture have been the most fascinating, mainly because of the widely different effects that have been reported. These include, among others, changes in intracellular free calcium (Rozek et al., 1987), increased synthesis of DNA (Liboff et al., 1984), increases (and decreases) of cell motility (Smith et al., 1987), altered cell proliferation (Libott et al., 1993), and changes in immune response (Caddosi et al., 1992).

Childhood leukemia

The original 1979 study by Wertheimer and Leeper (1979) claimed that children living in homes exposed to 60-Hz magnetic fields from nearby power lines have a twofold higher probability of developing leukemia. Presently, despite the lack of a credible mechanism, and the occasional negative study, there is a preponderance of studies in support of Wertheimer's original work. No one has yet done the laboratory experiment that convincingly reflects the epidemiological conclusions. Part of the difficulty in performing this much needed laboratory work are the small magnetic intensities that are involved, namely 2–4 mG, often difficult to achieve in a reproducible manner in biological settings. Furthermore those supporting research in this area, such as the Electric Power Research Institute, the Department of Energy, and the National Institute of Environmental Health and Safety, have not emphasized the study of fields this small; thus a good deal of research has been done at 1 or 2 G, lev-

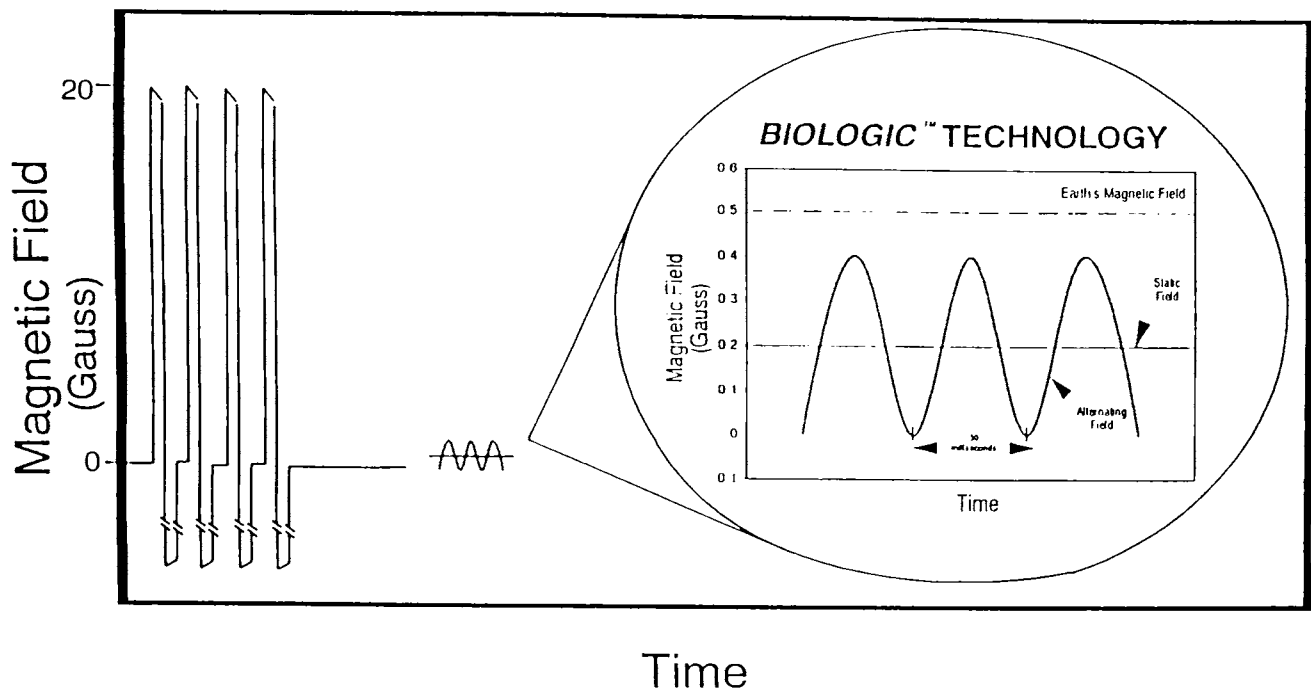


FIG. 1. Comparison of two magnetic waveforms used in the treatment of bony nonunions. To the left is a pulsed magnetic field (PMF) signal; to the immediate right of the PMF waveform an equally effective ion cyclotron resonance (ICR) signal is displayed. The PMF signal, applied as a burst of pulses, rises to a maximum magnetic intensity of approximately 20 G. The ICR signal, sinusoidal, with a peak intensity of only 0.20 G, is also shown on an expanded scale. (Courtesy of the OrthoLogic Corporation, Phoenix, AZ).

els; 500 to 1000 times larger than the intensities implicated in the epidemiological work. The result is that the epidemiological studies and the laboratory work still remain rather disarticulated.

Plant growth

It has been reported (Smith et al., 1993) that the early growth stages of plants and trees are sensitive to time-varying magnetic fields. There is even evidence that separate parameters (eg, leaf size, plant height, root mass) of plants can be individually controlled.

Rat behavior

Perhaps most relevant to our understanding of acupuncture is the convincing body of work showing that low-frequency magnetic signals can affect brain function. This comes as little surprise considering the electroencephalographic (EEG) signal is itself an electromagnetic product of the central nervous system. What is surprising are the effective intensities, again very weak, of the order of a few hundred mG, if not lower. (The earth's magnetic field is approximately 500 mG).

Bawin and Adey (1975) determined that the rate of efflux of radioactive calcium from samples of prelabeled chick brain is a sharp function of (electric field) frequency, reaching a maximum at about 16 Hz. In this widely repeated work, referred to as the calcium-efflux experiment, the low frequency was applied as a modulation frequency, on top of a radiofrequency carrier signal. Blackman (Blackman et al., 1985) changed the experimental design, using magnetic fields instead of electric, as in Adey's experiment, and concluded that the efflux was dependent on the local DC magnetic field. Liboff (1985) showed that the combination of effective frequencies and DC magnetic intensities used by Blackman followed an ion cyclotron resonance (ICR) signature corresponding to the charge-to-mass ratio of the potassium ion; later, in Thomas' laboratory at the Naval Medical Institute in Bethesda, the short-term (24-hour) memory of rats that were exposed to combinations of magnetic field corresponding to the charge-to-mass ratio of the lithium ion (Thomas et al., 1986) was significantly affected (Fig. 2).

This resonance work was extended at the Battelle Pacific Northwest Laboratory (Lovely

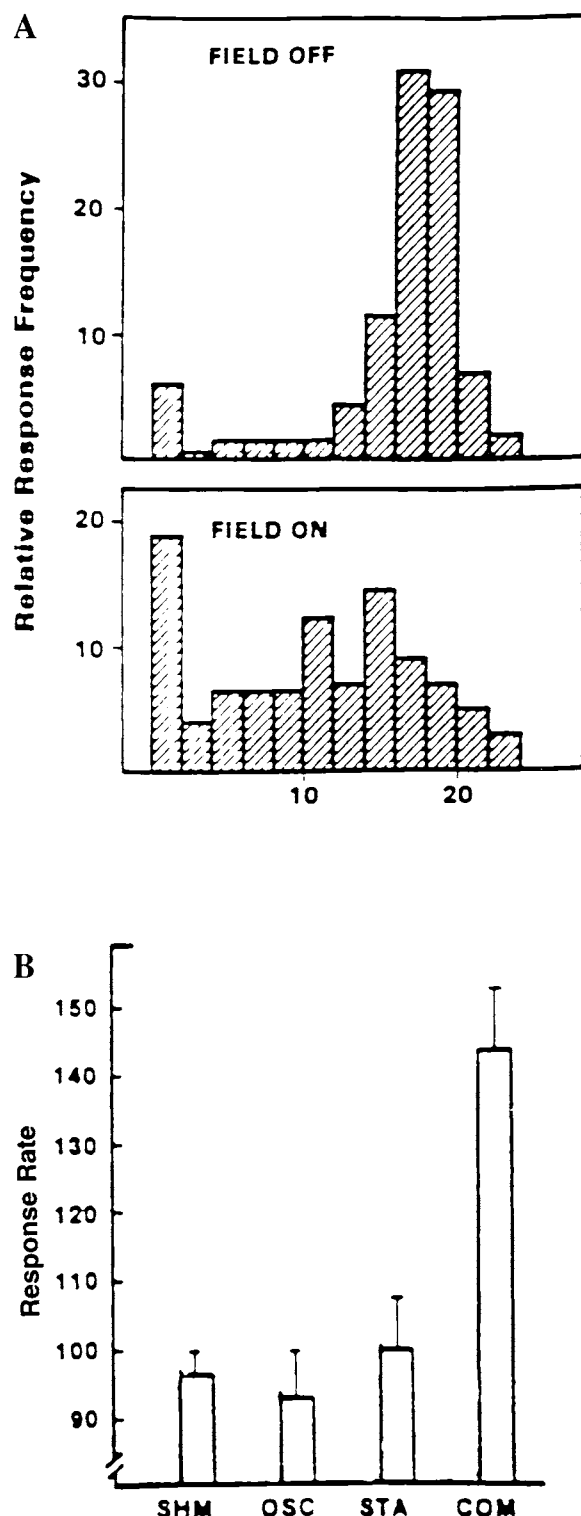


FIG. 2. Effect of an ICR magnetic signal on time discrimination in pretrained rats (19). (A) A rat trained to wait 18 seconds after a light cue to push a lever responds as shown in the upper box. After exposure to the ion cyclotron resonance (ICR) field combination for 30 minutes, the sharp response at 18 seconds disappears. (B) The importance of the ion resonance magnetic combination: the only response different from that observed using a sham exposure (SHM) occurs when the DC and AC fields are applied simultaneously (COM). When exposed to either the AC field alone (OSC) or the DC field alone (STA) the rat's timing discrimination is unaffected, and indistinguishable from the sham exposure. The ICR magnetic field combination used in this experiment was a DC field of intensity 0.26 G and a parallel AC field with a frequency of 60 Hz.

et al., 1993). Rats in a Y-maze were exposed to ICR magnetic field combinations tuned to the charge-to-mass ratios of first magnesium, and then calcium. The rats learned the maze more rapidly under the magnesium field tuning but more slowly in the calcium field, a result suggesting possible involvement of N-methyl D-aspartate (NMDA) receptors. Recently, a Russian group (Lyskov et al., 1995) successfully replicated a portion of the Battelle results.

The hippocampal output frequency of rats were studied extensively by Jenrow in our laboratory (Jenrow, 1995). When rats are exposed for an hour to (nonresonant) weak magnetic fields at frequencies different from the strong rhythmic (3 Hz) electrical activity emanating from the CA1 region of the rat hippocampus, this output signal either becomes entrained to the magnetic frequency, or is completely altered, depending on the applied magnetic field frequency. In either case, the new electrical response of the hippocampus is maintained well after the magnetic field is removed.

UNDERLYING PHYSICAL MECHANISM FOR BIO EM EFFECTS

A number of hypotheses have been generated to attempt to explain the body of laboratory and epidemiological bioelectromagnetic evidence. These explanations include, among others, mechanisms related to: (a) Faraday induction; (b) magnetite inclusions; (c) free radical recombination; and (d) ICR.

Faraday induction

Faraday induction produces an electric field in the presence of a changing magnetic field. If conducting materials (such as biological tissue) are present, the induced electric field will result in electrical current within the material. However, it is unlikely that even moderately weak extremely low frequency (ELF) magnetic fields, say, at 100 mG intensities, are sufficiently intense to induce biologically significant currents in tissue.

Magnetite inclusions

There is little question that magnetite does occur naturally as microscopic inclusions in

various species (Kirschvink, et al., 1992), but exactly how these inclusions, even if they are present, give rise to the reported bioelectromagnetic effects, has yet to be determined.

Free radical recombination

Magnetic fields down to about 10 G are thought (Harkins and Grissom, 1994) to influence the rate of recombination of free radicals, but this 10-G level represents an absolute lower limit. There is fully a factor of 5000 between 2 mG, the level implicated in the epidemiological studies mentioned above and this 10-G lower limit for free radical effects.

Ion cyclotron resonance

As an alternative to these ideas we proposed in 1985 (Liboff, 1985) that an ICR phenomenon may be responsible for many of the experimental ELF reports, as well as the epidemiological findings (Liboff and McLeod, 1995). More than 50 specially designed experiments to test this hypothesis in cells and animals have since been carried out, with mostly positive results. ICR requires the simultaneous application of both a static and a time-varying magnetic field. Resonance is achieved in a very precise fashion for different biological ions when the ratio of AC frequency to DC magnetic intensity equals the charge-to-mass ratio of the ion. The ions for which resonance have been attempted include Ca^{2+} , Mg^{2+} , K^{+} , and Li^{+} .

Originally, the author suggested that membrane-bound ion channels were likely sites for such resonance interactions. There are good reasons for this. The interior of the channel has a vacuum-like quality because ions pass through with relative ease. Also the channels are fabricated of proteins that thread through the membrane in a specifically helical manner. For basic physical reasons one expects the trajectories of ions undergoing ICR (in a vacuum) to move in a helical way. However suggestive these and other reasons are, deeper analysis clearly shows that the ion channel approach leaves much to be desired (Liboff, 1985).

More recently, Lednev proposed (Lednev, 1991) a new site for possible ICR interactions, namely calcium-binding proteins such as calmodulin. A variation on Lednev's model has

also been advanced by Blanchard and Blackman (1994) after their observation that neurite growth rates can be altered by ion resonance fields tuned to the charge-to-mass ratio of protons.

These theoretical models suffer from the same intrinsic difficulties as found in the original idea. The scattering of ions due to collisions at biological temperatures appears to be too great to allow any meaningful effects from exposures to weak ELF magnetic fields, whether the interaction site is an ion channel or a calcium-binding protein. In essence the problem is that ICR is observed in physics for regions where there is a vacuum, or at least a region with drastically reduced scattering compared to what occurs in biological tissue. Thus, despite the fact that the ICR explanation seems to be the only one that gives correct experimental answers, it is still regarded as more empirical than theoretical, simply because no one has yet been able to figure out a credible way of achieving resonance for ions in the inherently noisy biological milieu.

IS THERE AN ELECTROMAGNETIC BASIS TO ACUPUNCTURE?

Much of the connection between acupuncture and electricity derives from the fact that neurophysiological responses result from acupuncture stimulation. We know that certain points on the surface of the body are sensitive to either mechanical or electrical stimulation, that such stimulation can lead to systemic or topical changes elsewhere, and, above all, that central nervous system activity can be correlated (Pomeranz and Stux, 1989) with this situation, especially the pain response.

One concept is that application of needles to the acupoints changes the local electrical state, and that this change of state is communicated either by the peripheral nervous system, or along meridians, through the brain, to other points, to pain-suppressing synaptic junctions, or to internal organs. For example, Figure 3, adapted from Becker (1990), suggests that the local electrical field is sufficiently altered by the needle at the acupoint to block the transmission of pain signals.

However, less is known about the in-be-

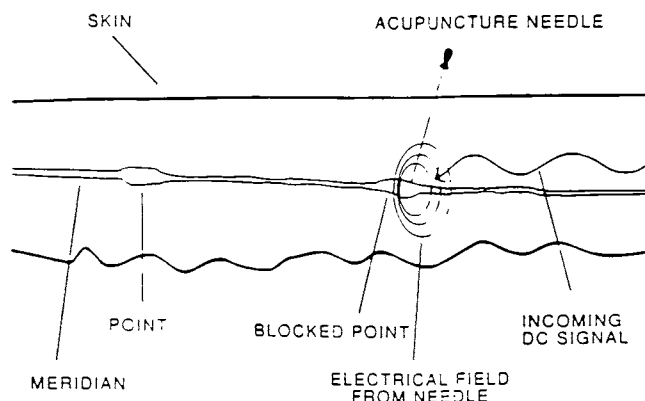


FIG. 3. Model after Becker (1990) indicating blockage of pain transmission due to electric field perturbation at acupoint.

tween details. Much of the mystery about acupuncture can be summarized in just two questions:

- first, what are the information routes for the stimulation signal, and,
- second, what are the physical attributes of the acupoints.

Traditionally the information pathways have been mechanistically described as meridians,¹ roughly comparable to the meridians, or lines of longitude, that divide the surface of the earth from pole to pole. Given a network of acupoints that are presumably interactive, one can readily imagine interconnecting links, much like, say, a railroad map of Great Britain.

On the other hand, neural signaling is not limited to straight-line paths. Furthermore, one only has to look at the release of catecholamines by the adrenal glands to realize that there are other than strictly neural ways to convey physiological information. Lacking any definitive experimental evidence as to what actually occurs at the acupoints, much less for the existence of meridians, we nevertheless can conceive of three possibilities, not necessarily independent, for the ways meridians might work:

- (1) *Strictly neural*: meridians are merely spe-

cialized but unnoticed neural pathways, highly differentiated and anatomically distinct, complete with synaptic links.

- (2) *Electrical*: they represent high-conductance "tunnels" embedded in otherwise normal, but higher resistance tissues.
- (3) *Chemical*: the intervening tissues between acupoints are uniquely sensitive to biochemical products arising at the acupoint, resulting in processes not unlike directed diffusion.

If we restrict our attention to just these three choices, it is clear that the first possibility is more reasonable than the third. This follows from the syllogism: anesthesia is a specific neural response. Acupuncture can lead to anesthesia. Acupuncture therefore must have a neural basis.

The second possibility, that meridians represent electrical signaling networks distinct from the (anatomically defined) nervous system is an interesting construct, albeit rather speculative. A similar idea, due to Nordenstrom (Nordenstrom, 1983), suggests the vascular system acts as a low-resistance pathway to carry physiologically encoded electrical information.

One can also approach the question of the electrical character of meridians in a more holistic way. In the 1930s at Yale University, Harold Sexton Burr (1972) suggested the existence of what he called the L-field, an electrostatic field connected to the surface potential of humans, through which one's wellness was maintained. Becker later argued (Becker and Seldin, 1985) that all chordates may carry a global head-to-tail electric field distribution, similar to that shown in Figure 4. For comparison's sake, the electric field surrounding an electric dipole distribution of charge is also shown. Electric dipoles are characterized by equal amounts of positive and negative charge separated along a line. Marsh and Beams (1952) were able to reverse the head and tail of a regenerating planarian by first assuming that there is an innate dipole polarity that distinguishes head from tail, and then applying a small DC voltage along the planarian axis opposite to the original electric polarity. Lund (1947), Jaffe (1973), and Pohl (1981) found further evidence for such an electric dipole distri-

¹We advise against the attempts to rename the meridians as channels, because of the potential for confusion with the membranes ion channels studied in physiology.

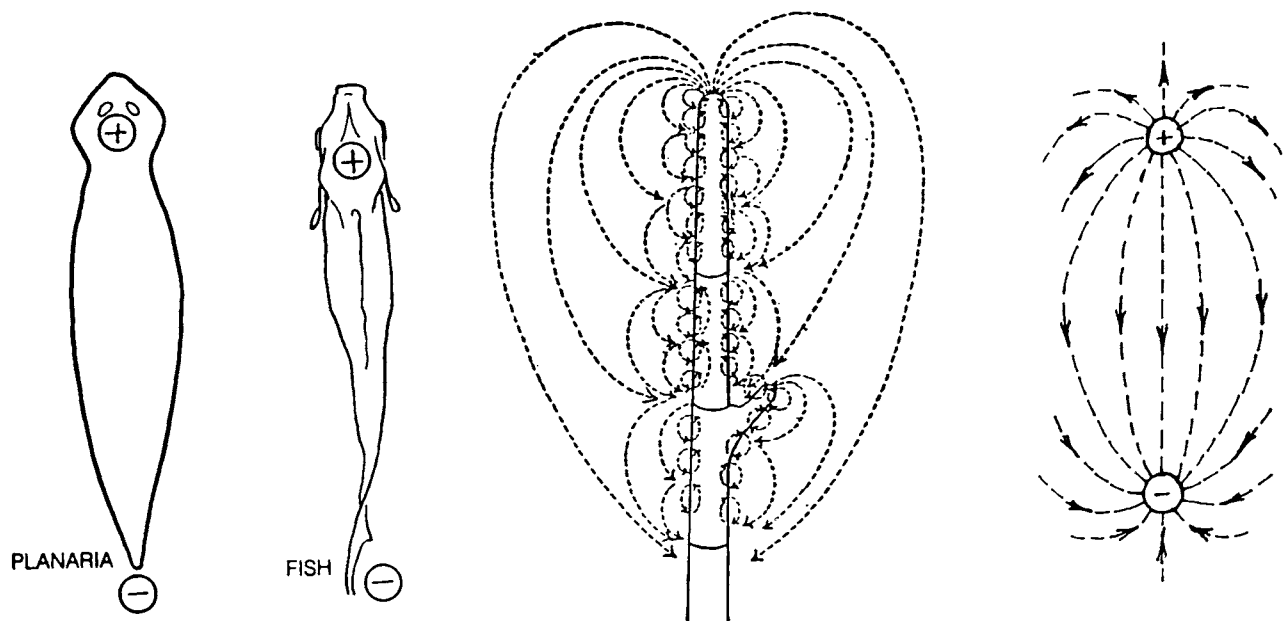


FIG. 4. Axial distribution of electric field associated with living systems. From left to right, planarian and fish (Becker and Seldin, 1985), root tip (Lund, 1947) and electric field surrounding two separated equal and opposite charges (electric dipole).

bution, in root tip, in developing embryo, and in cell culture, respectively. Smith used similar ideas in his pioneering experiments on limb-bud regeneration (Smith, 1967). Another critical contribution to these ideas was the series of experiments by Athenstaedt (1969) showing that the electric polarization intrinsic to the skeletal system in human and other animals is a function of age, greatest in infancy and falling to a constant value with maturation.

Thus, one finds evidence in the literature hinting that some type of global electric dipole field is present in living systems. Is this dipole field the basis for acupuncture meridians? Unfortunately, this question presently remains unanswered because these provocative experiments, all performed years ago, have never been followed up. What is clearly needed in the attempt to relate electric fields to acupuncture meridians is to revive this all-but-forgotten research in basic electrobiology initiated decades ago by Lund, Becker, and others.

Despite the less than satisfactory evidence that might help convince us of the existence of meridians or explain their underlying properties, acupoints themselves seem to be on much firmer ground, if for no other reason that they are routinely used in everyday practice.

The author views the distribution of acupuncture points over the surface of the

body as analogous to the distribution of receptors over the cell surface. Cellular receptors provide an important means of communication between the outside world and the cell interior. In essence they are low-resistance pathways through the high-resistance cell membrane. It therefore should not be surprising to find similar entities in macroscopic, multicellular, living organisms. Acupoints, in this fractal-like view, may play the same role for the entire organism as receptors do for individual cells.

To be sure, higher order animals all enjoy a wide range of sensing devices, each of which is far more specialized and complex than are receptor/protein channels in cell membranes. Nevertheless, it may not be unreasonable to anticipate, along the lines first suggested by Becker (1963), that the remnants of a primitive nervous system still persists in humans, and that this system is electrical in character.

In part, this hypothesis is derived from the various studies that have demonstrated the existence of the "current of injury" (Fig. 5), the change in local electrical field after radical changes in body structure, such as a fracture or amputation (Friedenberg, et al., 1973). One of Becker's major contributions to this literature was to suggest that the disturbed electric field surrounding a salamander stump after amputation is akin to the current of injury observed

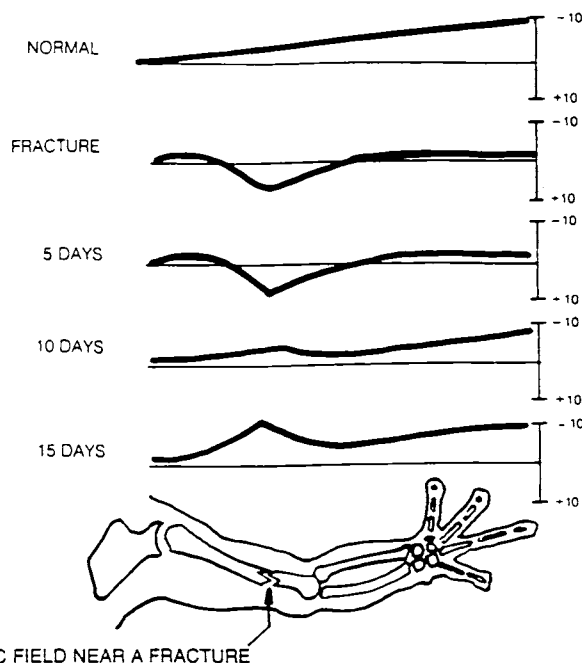


FIG. 5. Example of current of injury, as measured in frog (Becker and Seldin, 1985). Immediately after a fracture, the electric potential reverses at the break. As the healing process ensues, the potential at this point reverses once more before finally returning to the original normal voltage.

in higher animals. This leads to the generalization that the current of injury is not merely an epiphenomenon, but likely plays a role in the repair mechanism, whether the problem is a fractured bone in human or an amputated stump in salamander. Thus, the experiments by Smith, Becker, and others, attempted to regrow excised limbs or missing nervous tissue where polarized voltages are applied to the impacted tissue, directed so as to reverse the polarity of the field that appears following the injury. This idea that biological systems manifest an electrically guided repair system is very consistent with the first concept mentioned above, namely that under stasis, biosystems carry an intrinsic electric field. When anatomic changes occur, this field is perturbed, and the system somehow utilizes the change in electric field to restore itself.

One additional aspect of acupuncture practice is the role of mechanical pressure. The twirling of an acupuncture needle can be regarded as providing a periodic pressure to the acupoint. It has been long known that one important physical characteristic of collagen fibers is their intrinsic piezoelectricity, ie, their

ability to electrically polarize under mechanical stress. This property has been demonstrated in Achilles' tendon (Fukada, 1968), and even in tissues having far lower concentrations of collagen, such as dentin (Liboff and Shamos, 1971), long bone (Shamos and Lavine, 1967), and vascular tissue (Fukada, 1968). Marino and Becker (1970) provided a strong argument for a homeostatic control system using the piezoelectric effect in which mechanical stress on the skeletal system is transduced electrically to direct the differentiation of stem cells to become either osteoblasts or osteoclasts, thus providing the means whereby bone is enabled to remodel depending on its mechanical environment (Wolff's law). In a possible extension of such electromechanical ideas to acupuncture, one might be tempted to pursue the idea that acupoints contain electromechanically sensitive dense collagenous structures that are in close proximity to elements of the nervous system.

Finally, we note that the cell membrane is a rather efficient electrical insulator. To be detected within the cell, exogenous electrical signals must contend with an electric field strength of about 10^7 V/cm spanning the cell membrane. As such, it is difficult to understand how changing the external electrical field can affect internal cellular components. For this reason, it seems more reasonable to think of the acupuncture interaction as one necessarily involving receptors and ion channels.

We know that cells aggregate for purposes of support and separation. Typical examples of such cells packed on top of one another are found in the periosteum, the intestinal lining, the vascular system, and in the skin. Perhaps it would not be surprising to find nonexcitable cells organized not only for mechanical and chemical purposes, but also for electrical reasons.

Cell sensitivity to local electrical fields or currents at acupoints would be enhanced if there were increased receptor density in the cells local to these regions. Alternatively, it is conceivable that cellular receptors and/or membrane channels might be preferentially oriented at these points, with each such signaling detection system similarly arranged over many cells. Finally, we note that there is already in existence an elaborate cell-to-cell communica-

tion system found throughout the body, that involving gap junctions, connecting links between adjacent cells that serve to transmit information over many cells in a rapid manner.

EXPERIMENTAL SUGGESTIONS

Even if we presently think that the acupuncture mechanism is primarily electrical, and not magnetic, it is well to remember that research in bioelectromagnetics was almost entirely based on effects due to electrical exposure until Blackman's experiment (Blackman et al., 1985) in 1985 showing the critical influence of the local magnetic field on the outcome of these effects. Since that time, it has become commonplace for those studying bioelectric phenomena to at least make note of the background magnetic field in their reports.

It therefore may be useful to also look to the dependence of the acupuncture response on the geomagnetic field. To the best of our knowledge, acupuncture studies have never pursued this possibility. The simplest approach would be to compare responses from one laboratory with another, to see whether differences might correlate with differences in geomagnetic orientation and intensity. A more systematic approach would be to design a series of experiments using a few subjects in a single laboratory setting and use the magnetic field vector as an independent variable to determine its effect on stimulation efficacy.

In the past few years a group of new devices have proven very successful in exploring the physical characteristics of surfaces. The scanning tunneling microscope (STM) is one such example. With few exceptions, their application has been limited to nonbiological surfaces. It is intriguing to consider the possibility of studying an individual's skin using the STM.

In other words, if one can expect an electrically distinctive characteristic to the skin directly above an acupoint (or above a meridian), then the STM might conceivably detect the change between regions of the skin close to and remote from an acupoint. The STM is routinely used to scan a surface and discern changes with resolutions better than tens of

microns (micrometers). In principle, therefore, the STM could readily resolve electrical changes in the skin surface from one point to another only fractions of a millimeter away. Two unresolved practical issues might make such measurements difficult, however. These are critical restrictions on motion when using the STM; it is not clear whether the palm of one's hand, for example, could be kept sufficiently still over the measurement time. Second, there are various weak electrical perturbations arising, for example, from the electrocardiogram, even in the extremities, and such noise might prevent detection of the desired surface signal.

FURTHER SPECULATIONS

It may be useful to try to put acupuncture into a larger context. A number of attempts have been made in the past few decades to model a more fundamental relation of biological systems to electricity or to electromagnetism than is currently believed, one that could perhaps help us rethink our 20th century emphasis on biochemistry, and, more recently, on molecular biology. To an extent, my own approach to the question of bioelectromagnetism has mirrored this type of thinking, as I have become more convinced that a new paradigm is emerging in the life sciences, one based on the notion that living organisms, over evolutionary times, have developed exquisitely sensitive responses to local EM fields, both endogenous and external. In promoting this view, I am not arguing that biochemistry is in any sense wrong, but rather that its usefulness in explaining things may be limited.

The best approach may be to re-examine the various ideas, mentioned above, examining the role of electric fields in living systems. The author has suggested a new way (Liboff, 1994, 1996) of encompassing these electric field concepts, along with magnetic fields, into a single electromagnetic vector field, intrinsic to each living entity. This vector field has properties determined by the charge and current distribution internal to the system, regardless of the microscopic origin of the charge, whether arising from enzyme, charge transport, nucleic

acid, sugar, interfacial cellular array, or neural element. As the system develops, whether over a single lifetime, or over evolutionary lifetimes, this electromagnetic (π -vector) field will reflect such changes.

Because the endogenous distribution of charge and current density is mainly a function of genome coding, it is clear that this field, abstract as it may be, can serve as an alternative to our usual way of describing living organisms, ie, what we refer to as the *visible* characteristics. More than other sciences, it is peculiar to biology that living systems are described in an anthropomorphic manner, that is in terms of what can be seen at visible wavelengths, in that region of the spectrum with which humans are comfortable. There is some motion away from measurements based on visible characteristics. The military relies greatly on night-vision scopes to detect other humans, using infrared wavelengths. At our institution, a multijunction SQUID magnetometer looks at the signals produced remotely from the body, from the heart (MKG), and from the brain (MEG). Thus, associating an EM field with an organism has one rather interesting consequence, namely that the extent of an organism is not physically limited to what we can see.

We can speculate that if such fields are indeed in place, and there is little question of their existence, only of their strength, then perhaps it would have been a good survival strategy during the course of evolution to use some means of detecting these fields. Another way of saying this is that a naturally occurring EM field attached to individuals implies the possibility of information transfer between individuals. And if individuals are capable of sensing the fields of others, it is not unreasonable to suggest that they would also be capable of sensing changes in not only the naturally occurring EM environment, but also those manmade changes in this environment that have become commonplace in recent times.

In any event, given this set of admittedly speculative suggestions, one could readily find a role for a connected electrically sensitive network distributed over the body surface and organs, and therefore a possible explanation for acupuncture.

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